we want to know whether it is the large or the small form which he met with. Again, on p. 73, when he talks of the "sheet of water or marshy ground which might attract the waders and sea-birds so commonly found near Oxford," is it not the east wind which drives the latter along the course of the Thames, rather than any peculiar attraction of the country near Oxford? The fact of the Cuckoo carrying her egg in her bill for deposit in the nest of her victims is now universally admitted; but what concerns ornithologists is the greater or less resemblance of the egg deposited by the female Cuckoo to the eggs of the foster-parents which she selects to bring up her young. The Spotted Flycatcher has undoubtedly a song (p. 83), but it is a poor affair, and is heard only, according to our experience, at daybreak. It is true that the Green Sandpiper (p. 86) has really only the legs greenish, but the reason of the perpetuity of the name to which our author objects, is because Linnæus called the species *ochropus*, and the name adopted by the older English writers was the *Green* Sandpiper, which has been handed down to the present generation, as is also the case with the Grey Wagtail. The author knows his "Dresser" and his "Harting," but he can learn something of the affinity of Robins and Redstarts (pp. 88, 101) from Mr. Seebohm in the British Museum "Catalogue" (vol. v.), or in his "History of British Birds." The little essay on the "Birds of Virgil" is most interesting, especially with regard to the *Alcyon*, which, we agree with the author and his authorities, was probably *not* our Kingfisher, though the presence of the latter on the sea-shore in some numbers is a fact at the season of the autumn migration. We offer these few remarks to the author as points of further study on which we should be glad to have the observations of a true naturalist, such as he evidently is.

The Rev. Gregory Smart has recently published a little book on the "Birds on the British List," which is a *critique* on the list issued by the British Ornithologists' Union, which he collates with the works of Mr. Dresser, Mr. Seebohm, and the fourth edition of "Yarrell." The book is disfigured by a slovenly style of writing, for which the printers' errors can scarcely account, and this is the greater pity, as the author's intentions are good, and he scores distinctly on several occasions when dissecting the evidence on which some birds are admitted to the British List while others are rejected; but the English in which he endeavours to record his conclusions is, to say the least of it, a little mixed. The author confesses to "having had but little experience," and it would therefore have been better to have restricted himself to the main object of his book, viz. the criticism of the evidence on which some species are retained or rejected in the works above alluded to. When he gets outside the boundary of his *critique*, he talks in some instances simple nonsense, as in his remarks on the Gold-vented Bulbul (p. 18). Mr. Dresser and Mr. Bidwell, in aiding and abetting Mr. Smart in his hap-hazard identification of his Bulbul's egg, could scarcely have expected the punishment of having their rash opinion published to the world. On p. 41 some more nonsense appears about *Anthus ludoricianus* and *A. campestris* being conspecific! The author would seem to be unaware that "Ungaru" is generally spoken of as "Hungary" by English writers, and that "Los Angelos Cala" is a locality which will puzzle many an "inexperienced" collector for whose benefit Mr. Smart professes to write. We would advise the author, before publishing another book, to get some friend to look over his manuscript for him, as a good deal of the difficulty of unravelling the meaning of his sentences would have been avoided by a simple attention to stops and commas, which is not too much to expect from a "late Scholar of Trinity College, Cambridge."

R. BOWDLER SHARPE

SOLAR PHYSICS[1]

MOST of our readers are aware that the sun, as constructed by Zöllner, was a white-hot, liquid body, that its spots were scoriaceous products of local cooling, and that its atmospheric circulation was closely modelled upon the terrestrial, with trades and anti-trades, an equatorial belt of calms, land- and sea-breezes, the last due to the contrast of temperature between the slag-islands constituting spot-nuclei, and the incandescent ocean in which they floated. On these lines M. Schulz has reared a solar edifice out of materials to a large extent new. Sixteen additional years of results in one of the most rapidly progressive branches of modern physical astronomy, give him an advantage over his predecessor, utilised to the utmost in modifying, extending, and generalising views of which he is the intrepid, though not blind, partisan. The upshot, we venture to assert, is to prove them wholly untenable. If M. Schulz's ingenious advocacy fail to recommend them, their inherent weakness must be great. Our readers shall judge for themselves of its success.

In the work before us it is undertaken to account for the whole array of solar phenomena, from the conservation, through long geological ages, of the solar activity, and its cyclical fluctuations, to the production of a pore or a facula. With this alluring prospect in view we are invited to regard the sun as a liquid globe composed of unknown substances, glowing at a temperature somewhere between 10,000° and 20,000° C. Although the heat rises towards the centre by a very low gradient, the inequality suffices to insure the distribution of the loss by radiation throughout the bulk of the globe, vertical convection-currents carrying down the cooler and heavier outer layers, and replacing them with hotter and more buoyant materials from the interior. Thus the danger is averted of the light-and-heat-giving career of our luminary being brought to a premature close by the untimely formation of a crust. The relative permanence of that career is further secured by the application to a liquid sun of Helmholtz's gravitational principle of the maintenance of solar heat.

The extensive atmosphere surrounding this molten mass is composed mainly of the unknown gas emitting Kirchhoff's "1474" line. This, in M. Schulz's opinion, is the primitive and simplest form of matter. Its atoms, many times lighter than those of hydrogen, are the fundamental units by the various aggregation of which the atoms of all other substances whatsoever are constructed. It plays, as we shall presently see, a very important part in the solar economy devised by our author. The solar supply of it is on a prodigious scale, since it fills, mixed with small percentages of hydrogen, helium, and metallic vapours, the vast spherical shell visible during total eclipses in the form of a "corona."

In the lowest strata of this gaseous envelope the photosphere hangs suspended at a height of a few thousand miles above the real surface of the sun. Its structure resembles that of our cirrus-clouds, only that metallic and incandescent condensing particles are substituted for aqueous frozen ones. The Fraunhofer absorption M. Schulz brings about by the customary machinery of the "reversing layer," regardless of the growing objections on the part of leading solar physicists to its exclusive employment in that capacity. Indeed the details of spectroscopic evidence scarcely receive from him the minute attention they deserve. Mr. Lockyer's researches on "lines widened in spots" give an example of the kind of work that has henceforth to be done on the solar spectrum. Summary explanations of its phenomena no longer suffice. Each one of its thousands of dusky rays has an individual story to tell, well worth the trouble of inquiring into. Each has its own significance, and might be made the subject of a separate, and not unfruitful, study.

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[1] "Zur Sonnen-Physik." Von J. F. Hermann Schulz. Separatabdruck aus der *Gaea*, Bände xxi. und xxii., 1885-86. (Leipzig: W. Drugulin, 1886.)

Prominences and spots are, by our author, connected together as cause and effect, but in the inverse order of their probable occurrence. There are strong grounds for the belief that the initial disturbance is that which occasions a spot, eruptive appearances ensuing consequentially. But, if M. Schulz's account of the matter were correct, no spot could arise without an introductory display of spontaneous and preliminary flames. Prominences, in his scheme, are composed exclusively of the green coronal gas "1474." It is true that in the spectroscope lines of hydrogen and helium are visible, but their meaning, we are told, has been misinterpreted. They take their origin, not from the body of the prominence, but from the glowing sheath with which the resistance of the solar atmosphere to its upspringing encompasses it. This surprising contention refutes itself. The implied resistance would, in a few seconds, shatter into inconspicuousness the rushing volumes evoking it. "Quiescent prominences," moreover, would on this theory be impossible; yet they are often plainly visible, for weeks together, in virtually unchanging forms; to say nothing of spectroscopic incompatibilities, too obvious to need dwelling upon.

The mechanical power consumed in the projection upwards of these bodies is derived from the expansive force of gas escaping from tremendous pressure. In dilating, however, it loses heat, and at such a rate that by the time the pressure upon it is reduced from ten million terrestrial atmospheres to one tenth of an atmosphere, its temperature has fallen from 12,000° to – 216° Centigrade. The ensuing condensation to the liquid and thence to the solid state brings about a fall of "1474 snow" upon the photosphere. When the shower is a light one, a "pore" is the consequence; when it is heavy and long-continued, the cold falling matter reaches the liquid sheet beneath, a group of "slag-islands" is formed from the chilly contact, and a spot becomes apparent to distant onlookers. The overlying photospheric clouds then arrange themselves, under the influence of atmospheric currents, into the characteristic funnel-shape of the penumbra, at the bottom of which lies the obscure solid nucleus, more or less veiled in dense absorbing vapours.

Improbability raised to an infinite degree becomes impossibility; and we may safely assert that that degree has here been reached. Criticism is silent in the presence of a supposition so fantastic as that of a substance presumably far less condensable than hydrogen existing frozen in the very depths of the thrice-heated furnace of the sun.

So much for prominences and spots: we now come to faculæ. They are regarded by M. Schulz as mere optical effects of irregular refraction in the agitated vicinity of spots. Yet the plainest ocular proof of their being real elevations above the general level of the photosphere is afforded by their not unfrequent visibility as projections from the smooth border of the limb, as well as by Dr. De la Rue's relief-pictures obtained by the stereoscopic combination of photographs.

The (not undisputed) higher equatorial temperature of the sun supplies M. Schulz, as it supplied Zöllner, with a "trade-wind" circulation, by means of which the retarded transport of spots remote from the equator are, with some difficulty, accounted for. Their slight displacements in latitude prescribe the mode of the sun's bodily circulation. A stupendous system of vorticose currents—set going by differences of specific gravity through surface-cooling—is disposed so as to impel such objects slowly towards the poles from about 15° of north and south latitude, while minor equatorial whirlpools give the observed opposite drift within those limits. But such an arrangement, even were it otherwise possible, would reverse Carrington's noted law of solar rotation, the angular rate of which would, under the supposed circumstances, *quicken* with advance poleward, while the maximum retardation would occur somewhere between ten and twenty degrees of latitude.

This rolling movement from within outward of the entire substance of the liquid solar globe, save a small dense nucleus, serves, however, a further purpose. It explains the spot-period.

The occurrence of spots, it must be remembered, depends primarily upon the escape of "1474" gas (which we may designate "coronium") from the interior. But how does it get there? M. Schulz's reply is to the following effect.

Coronium has a powerful affinity for a certain hypothetical solar constituent described as "spot-stuff." In middle and high latitudes a temperature as low perhaps as 9000° C. permits combination which accordingly takes place freely over a vast area. Huge masses of a compound of coronium with "spot-stuff" thus enter into the general circulation, and are gradually carried down to depths where a temperature enforcing dissociation is encountered, giving rise to the formation, under enormous pressure, of gigantic bubbles of pure coronal gas. By their variously-conditioned outbursts these finally occasion prominences and spots, which are more or less numerous according as the distribution of "spot-stuff" is more or less plentiful. Admitting some degree of permanence in its localisation, and assuming that the great vortices whirl once completely round in eleven years, the spot-cycle is established. The equatorial spot-and-prominence minimum finds its *rationale* in the higher temperature by which the occurrence of chemical association in any part of the separate equatorial vortices is prohibited.

We have endeavoured, while omitting details which it would be waste of time to dwell upon, to do no injustice to M. Schulz's ideas in our brief sketch of them. Yet it is difficult to treat them quite seriously; and we confess to a feeling of regret in seeing a writer of M. Schulz's ability and acquirements apply them to the elaboration of so baseless a series of hypotheses—baseless in this sense, that they rest upon a number of postulates which few will be disposed to allow. With sufficient liberality of assumption almost anything can be explained on any desired principles. But this is just the kind of supply which a prudent investigator is most chary of granting either to himself or others. For its misuse undermines the foundations of science, and involves in common discredit illusory theories and legitimate schemes of inductive reasoning.

It is not without cause that solar physicists have adopted what M Schulz calls the "gas-ball theory" of the solar constitution. A mainly liquid sun is for many reasons inadmissible. At a temperature of 10,000° C. and upwards, to begin with, no substance known to us upon the earth can exist otherwise than in a state of vapour. Hence the necessity for having recourse to unknown elements with preternaturally high boiling-points. But a theory of Nature built upon the unknown has, it must be admitted, no very secure basis. Further, the internal stores of heat of a liquid sun could not be made available at the surface. The heterogeneous materials presumably composing it would necessarily arrange themselves, in the order of their specific gravities, into a succession of shells growing in density towards the centre, which no possible convection-currents would have power to disturb. The result would be the formation of a crust, and—so far as we can see—the speedy and final cessation of the radiative function of our luminary.

Some of the points touched upon by M. Schulz are of great interest, and we cannot but feel grateful to him for emphasising them, however little we agree with his methods of elucidation. He shows, for instance, that an atmosphere of hydrogen could not, on any probable assumption as to temperature, extend much more than

3000 kilometres from the photosphere without producing an amount of pressure at its base which certainly does not exist. Yet the spectroscope tells us that incandescent hydrogen is actually present at a couple of hundred times that height. Nor can the anomaly be reconciled by supposing, with our author, the solar atmosphere to be chiefly composed of a very much lighter gas ("1474"), merely, as it were, adulterated with hydrogen. Even if we were satisfied to ascribe to "coronium" an almost impossible degree of elasticity, it would not avail to lift the mingled hydrogen one inch above its natural level. The law of diffusion does not abrogate the law of gravity. Each gaseous ingredient of a mixed atmosphere obeys its own law of equilibrium, as if it existed alone. It is true that the anticipated thinning out of oxygen at great heights in our own atmosphere has not been experimentally verified; but the incessant agitation of the air is believed to mask an effect which should otherwise be perceptible.

The action of a repulsive force, such as is visibly exerted on comets, has been invoked as a means of escape from this difficulty. The supposition has much to recommend it, and would remove a good deal of perplexity; it is, besides, countenanced by the authority of Dr Huggins. But the more tempting it appears, the more severely it should be tested previous to its admission, on other than a provisional footing, among the theories of science.

The slightness of resistance to motion in the solar neighbourhood is one among many indications of the extreme tenuity of matter there. Comets well-nigh graze the sun's surface without experiencing perceptible retardation; and millions of cubic miles of hydrogen sweep onwards or upwards at rates up to 250 miles a second, almost as if *in vacuo*. Since both the moving substance and the medium are incandescent, the varying viscosity of gases at high temperatures would claim attentive consideration in the matter, were it not that reliable data are unfortunately deficient.

The rotational peculiarity of the sun may, however, be said to dominate the problem of its constitution. Three classes of explanation are possible, and have found various degrees of favour. It may be produced by the fall of matter upon the photosphere, by the ascent of matter from beneath it, or by surface-currents. The last was the theory of Zöllner, and has been inherited from him by M. Schulz, but may be dismissed without hesitation as contradictory of known facts. M. Faye's hypothesis of vertical currents bringing up with them a smaller linear velocity is more plausible, but needs peremptory treatment to fit it to the required shape. It is remarkable that M. Belopolsky has lately deduced theoretically, on some not improbable assumptions, Spörer's empirical formula of the diminishing rate of the sun's rotation north and south from his equator (see NATURE, vol. xxxiv. p. 54). The coincidence is striking; but it must not mislead us. It is not enough that a cause be true; it must also be sufficient. Is there any likelihood of its being such in this case? We apprehend that the effects, even supposing them realised to the full, would be microscopic compared with those actually observed. If we take the mean density of the sun at double its superficial density (an outside admission), the maximum of gravity will occur below the surface, at a depth of one-sixth of the radius, and there the *theoretical* rotation-period comes out, by a rough calculation, about twenty-two days. But this period is not in reality complied with. The tremendous hindering power of friction intervenes. It occurs on paper only, and belongs even there but to a single stratum. The effects in superficial acceleration must be quite inconsiderable.

Acceleration from below failing, we turn to acceleration from above. And it has to be borne in mind that the mode of the sun's rotation is inferred from the movements of spots, and from them alone. But if spots be due, as generally supposed, to vaporous down-rushes, they must share in the augmented velocity brought by the materials forming them from regions of wider circumference; and this theoretical necessity is confirmed by the characteristic plunge forward attending the sudden development of these objects. If we assume further that the height of fall, consequently the added linear velocity, diminishes progressively with distance from the equator, the phenomena of spot-transport in longitude are satisfactorily accounted for. Just such a graduated elevation of the sources of spot-supply forms an integral part of Mr. Lockyer's "meteoric-ring theory" of sunspots, communicated to the Royal Society in May last (NATURE, vol. xxxiv. p. 251). The line thus struck out, however it may be modified by future experience, seems to lead, more naturally and easily than any other yet tried, to the solution of the problem of the sun's apparent rotation.

A. M. CLERKE

THE NEW OPTICAL GLASS

EVERYTHING that falls from the pen of Prof. Abbé of Jena relating to optical matters commands respect. His announcement therefore of the discovery of new kinds of glass specially adapted for the manufacture of lenses has been received with peculiar interest; and although details of information on various points are still wanting, enough has been published respecting the new optical glass to be worthy of more than passing notice.

All who have had anything to do with optical instrument-making know only too well the existence of the defect termed "irrationality of dispersion." When Hall and Dollond had independently shown that the chromatic dispersion of a crown glass lens might be corrected by combining it with a second lens of flint glass, a new impetus was given to optical research. The so-called "achromatic" lens in the hands of successive generations of opticians constituted the basis both of the modern microscope and of the modern telescope. But as greater and greater perfection in the construction of the "achromatic" lens was attained, it became apparent that perfect achromaticity was very far from being realised; for though two lenses might be found which should perfectly bring together two widely differing rays, such, for example, as the red of the line C of the spectrum and the blue of line G of the spectrum, it by no means followed that this pair of lenses would bring together to the same focus all other rays. On the contrary, owing to the "irrationality" of dispersion a "secondary spectrum" would always remain uncorrected.

The relation between the chemical constitution of a medium and its action on waves of light of different periods is one of those matters about which we are still profoundly ignorant. We know that a prism of glass does not spread out the waves in proportion to their wave-length, or to the frequency of their periods. A simple case of irrationality is afforded in the fact that a green ray which when viewed through one prism may lie exactly half-way between C and G in the spectrum will not lie exactly half-way when viewed through a prism of a different kind of glass. All that a combination of two lenses can do is to achromatise for two rays of the spectrum: it may very nearly achromatise for the neighbouring rays, but strictly speaking it only achromatises for two. For ordinary optical purposes we seek to achromatise for the red and the blue, so reconciling the end regions of the visible spectrum. For photographic purposes we achromatise for green and violet (or even ultra-violet) rays, reconciling the end regions of the photographically active spectrum.

To Dr. Blair, whose observations were published in the *Transactions* of the Royal Society of Edinburgh for 1791, we owe the suggestion to achromatise for three rays by using compound lenses of three different media. Blair, indeed made a most extensive examination into the dispersive powers of various media, and in particular of